REPRESENTATIVENESS OF BEYOND-DESIGN-BASIS ACCIDENTS LIST

HOW IT CAN BE REACHED?

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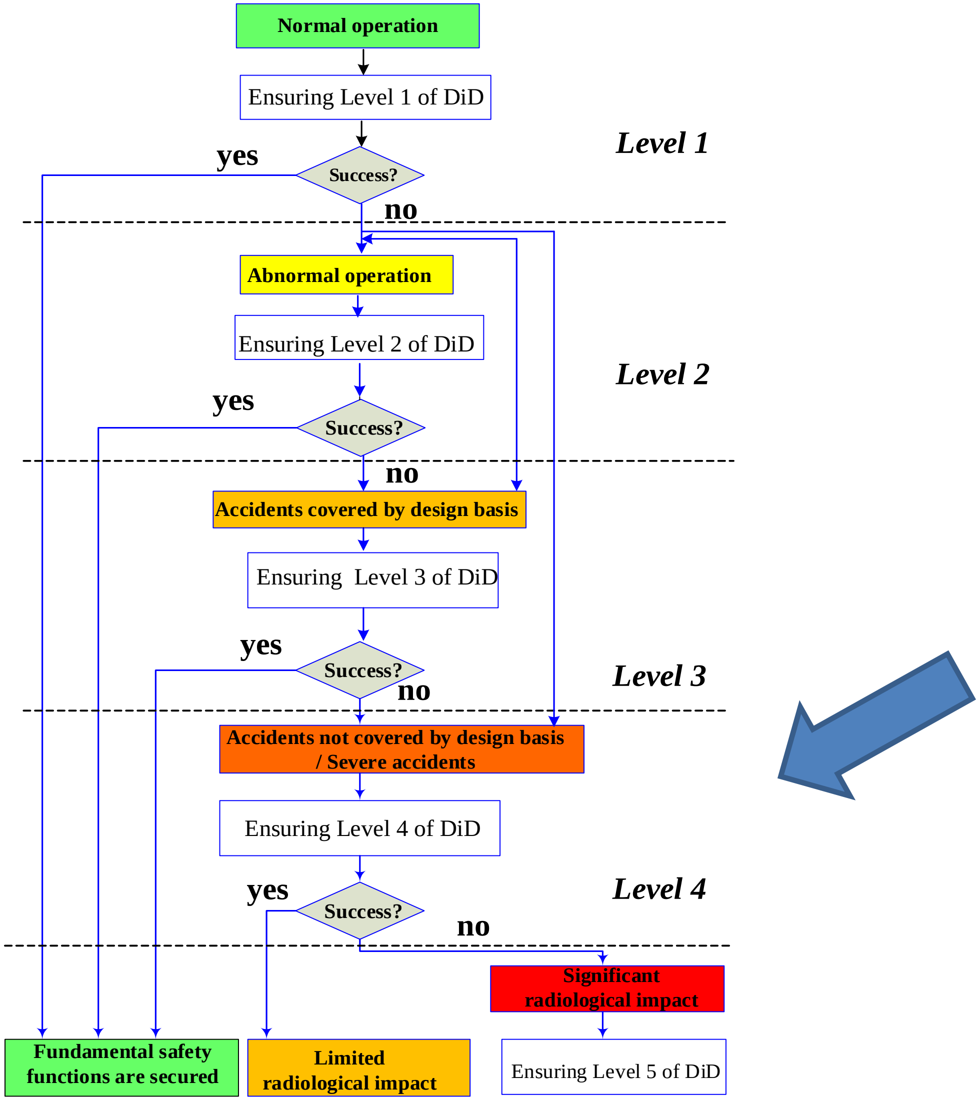


Place of BDBA management in Defense-in-Depth

National Regulatory Requirements for BDBA List

National regulations require to follow **two principles** when developing BDBA list:

1. Probability of BDBA should be evaluated, including those leading to large radioactive releases and additional technical measures of accident management provided for in case probability of exceeding of Large Release Frequency target value.

2. Representativeness (from the point of view of the planned emergency actions) of the accidents to be included in the Final list of BDBA for the NPP must be ensured

The 1st principle relates to plant design and similar to DEC concept of IAEA Safety Standard SSR-2/1.

The 2nd principle relates to Emergency Preparedness. Plant personnel shall know what to do if any accident happens included into Final BDBA list.

Provisional BDBA lists are presented in regulatory documents, while final BDBA list shall be presented in SAR.

Steps in making BDBA list

Step 1. Selection of areas where nuclear or radioactive materials are present at NPP

Step 2. Development of plant operational states list

Step 3. Making a list of initiating events

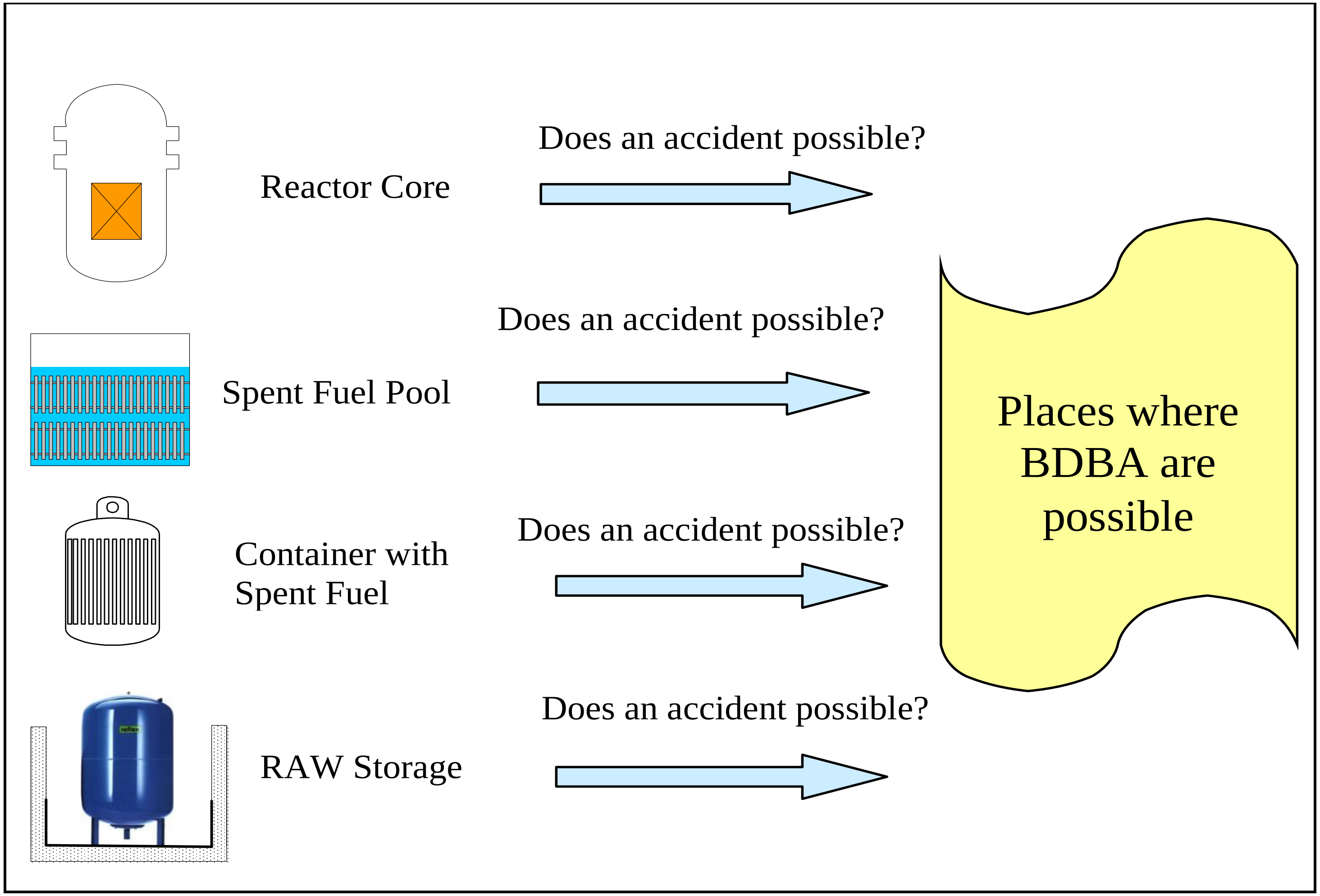
3.1 Internal events
3.2 Area events
3.3 External events

Step 4. Development of non-severe scenarios

Step 5. Development of severe scenarios

Final BDBA list

Step 1. Selection or areas where BDBA can occur

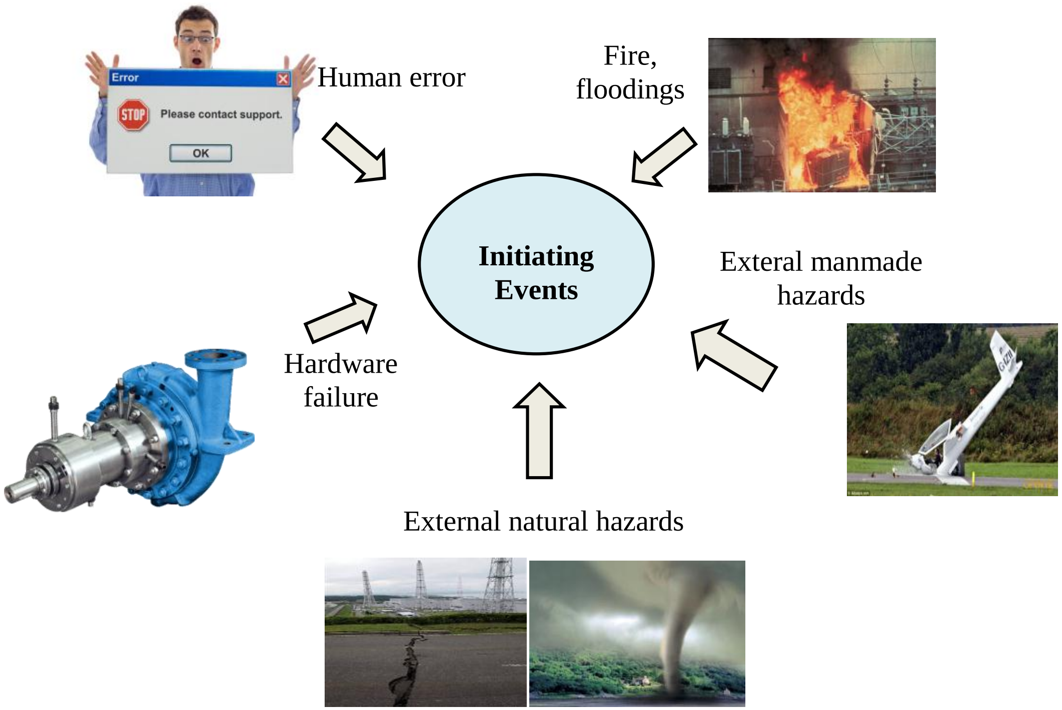


Step 2. Selection of Plant Operational States

Plant operational states	Possible IEs	Availability of plant systems
Nominal power operation	*IE Set-1*	*Configuration 1*
Power operation at partial level	*IE Set-2*	*Configuration 2*
Reactor cooldown	*IE Set-3*	*Configuration 3*
Hot state	*IE Set-4*	*Configuration 4*
Cold state	*IE Set-5*	*Configuration 5*
Reactor assembling and disassembling	*IE Set-6*	*Configuration 6*
Refueling	*IE Set-7*	*Configuration 7*
Hydraulic tests	*IE Set-8*	*Configuration 8*
Reactor warming up	*IE Set-9*	*Configuration 9*

Step 3. Developing Initiating Events List

Types of IE to be accounted for:



What is Initialing Event?

IE is an event which:

1) breaches NPP normal operation

and

2) necessitates a response from plant systems and/or operator to avoid progression into an accident (or leads to an accident irrespective of plant systems/operator actions).

If different initiating events require implementation of the similar response of NPP systems and operator they can further be grouped and considered as a initiating events group.

Step 3.1. Internal Initiating Events

The following sources of IE candidates are used:

- Failure mode and effect analysis for plant SSC;
- IE lists from the previously performed safety analyses, including PSAs for similar NPPs;
- Generic IE lists from the credible foreign and international information sources;
- Operating experience of similar NPP units.

Step 3.2. Fires and Flooding

- Fire zones (flooding zones) are established (premises /groups of premises or onsite areas, which are capable to confine the occurred fire (flooding) from propagation beyond the area within the specified time period);
- Occurrence of fire (flooding) is postulated in each of the fire (flooding) zones. Fires (flooding) in those fire areas (flooding areas), which satisfy the prerequisites for their assignment to initiating events, are included into the list of initiating events;
- Based on the operating experience of the analyzed and similar NPP units, the probability of occurrence of fires and floods in several areas simultaneously is to be assessed, and in case the probability of occurrence of such events is not negligible, their effect on NPP safety is analyzed.

Step 3.3. External Initiating Events

- For each of the external factors it is to be analyzed, whether there is a possibility of NPP normal operation disturbance and cause response of NPP systems or operator to prevent the external impact progression into an accident. All impacts, which are dependent against the analyzed one, should be considered;
- The probability of joint adverse impact caused by several factors is to be analyzed (the matrix of joint impact caused by external factors is used);
- If the NPP response for the same external factor differs under varying intensity of the considered factor, then the external impacts corresponding the same factor but having different intensity and requiring different response from NPP systems and operator should be considered as standalone initiating events.
- External impacts with the intensity equal to and beyond the design basis value. The number of gradations of beyond-design-basis impact intensity is to be specified by experts.

Step 4. From Initiating Events to Scenarios (Non – Severe)

Development of Non-Severe Scenarios

1. All failures dependent on an IE are to be detected. IE and the dependent failures are considered jointly.
2. A set of safety functions and their execution ways, which prevent accident progression into the severe accident, are to be specified for each IE.
3. Initiating events, for which it is impossible to prevent accident growth into severe accident, are to be excluded from consideration and subject to analysis in Severe accident analysis (Step 5).
4. For each group of IE the combinations of IE are to be distinguished: “IE” + “Failure to perform way K of execution safety function N”.
5. In case of available PSA model, the frequencies for implementation of the above-mentioned combinations of events are to be evaluated. For combinations of events, which have significant implementation frequency ($\sim 10^{-6}\ ^{1}/_{year}$ and above), the extra combinations are to be distinguished.
6. The check should be done that scenarios recommended by national regulatory documents, as well as by state-of-the-art international documents are considered (such as ATWS scenarios, plant blackout, loss of UHS and others).

Development of Non-Severe Scenarios

IE 1 + Failure of way 1 fulfilling Safety Function 1

IE 1 + Failure of way 2 fulfilling Safety Function 1

IE 1 + Failure of way 1 fulfilling Safety Function 2

IE 1 + Failure of way 1 fulfilling Safety Function 3

IE 2 + Failure of way 1 fulfilling Safety Function 1

IE 2 + Failure of way 2 fulfilling Safety Function 1

… …

IE N + Failure of way K fulfilling Safety Function M + Failure of way L fulfilling Safety Function P

IE N + Failure of way K fulfilling Safety Function M + Failure of way R fulfilling Safety Function P

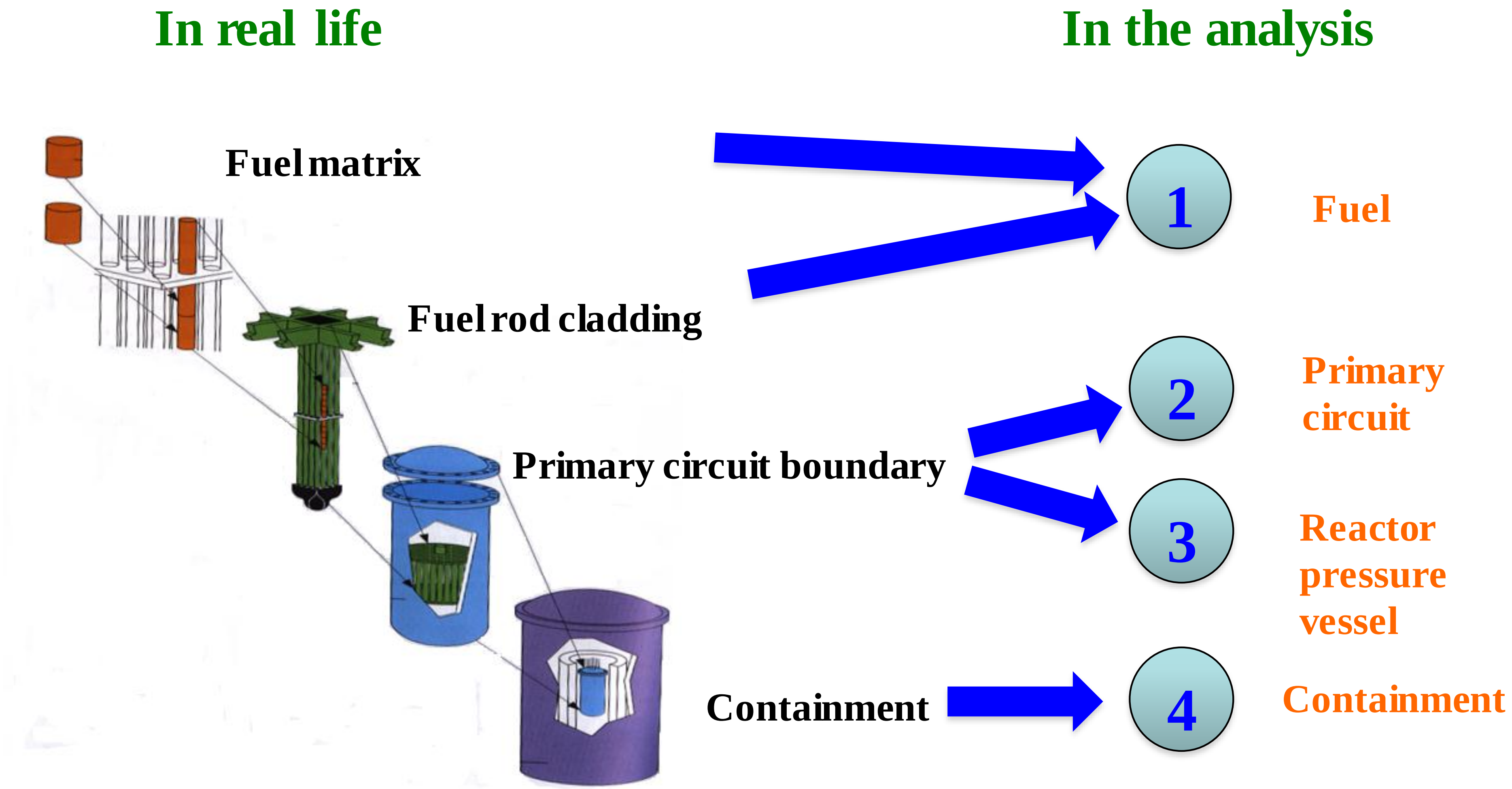
… …

Step 5. Development of Severe Scenarios

Development of Severe Scenarios

- The list of physical barriers, as well as of safety functions, the state of which influences the severe accident management strategy is to be compiled.
- For each physical barrier and safety function the gradation of states is to be developed starting from the complete effectiveness of a physical barrier (safety function) to complete ineffectiveness, thus to provide that different states of physical barriers (safety functions) would require implementation of different strategies on BDBA management.
- The generalized event trees, reflecting IE progression into different severity levels states depending on implementation or non-implementation of the assigned safety functions, are to be developed. Accident sequences of the generalized event trees are to be developed until the final state that can be maintained for an unlimited time period is achieved.
- The final BDBA list includes severe scenarios, corresponding to each branching point of the developed generalized event trees.
- A check is to be performed to verify that the developed generalized event trees reflect NPP states assigned to severe accidents recommended by the national regulatory documents.

Set of Physical Barriers



Scale of Physical Barriers States

Fuel (FU)

FU 1 – Fuel damage does not exceed design limits (total loss of tightness is possible)

FU 2 – Severe fuel damage exceeding design limits for fuel damage

FU 3 – Total fuel damage or melting

Primary circuit (PC)

PC 0 – Primary boundary is intact

PC 1 – Very small & small leakages inside containment

PC 2 – Medium and large leakages inside containment

PC 3 – Primary coolant evaporation through PORV

PC 4 – Primary to secondary leakages

PC 5 – Primary leakage to adjacent systems.

Reactor vessel (RV)

RV 0 – Reactor vessel is intact

RV 1 – Pressure vessel rupture at high primary pressure

RV 2 - Pressure vessel rupture at low primary pressure

Containment (CN)

CN0 – Containment leakage within design limits

CN1 – Containment leakage exceeds design limits

CN2 – Containment failure resulting from basement penetration

Severity Levels

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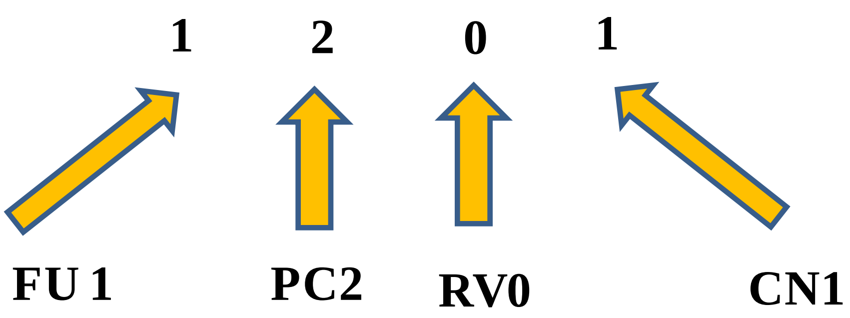
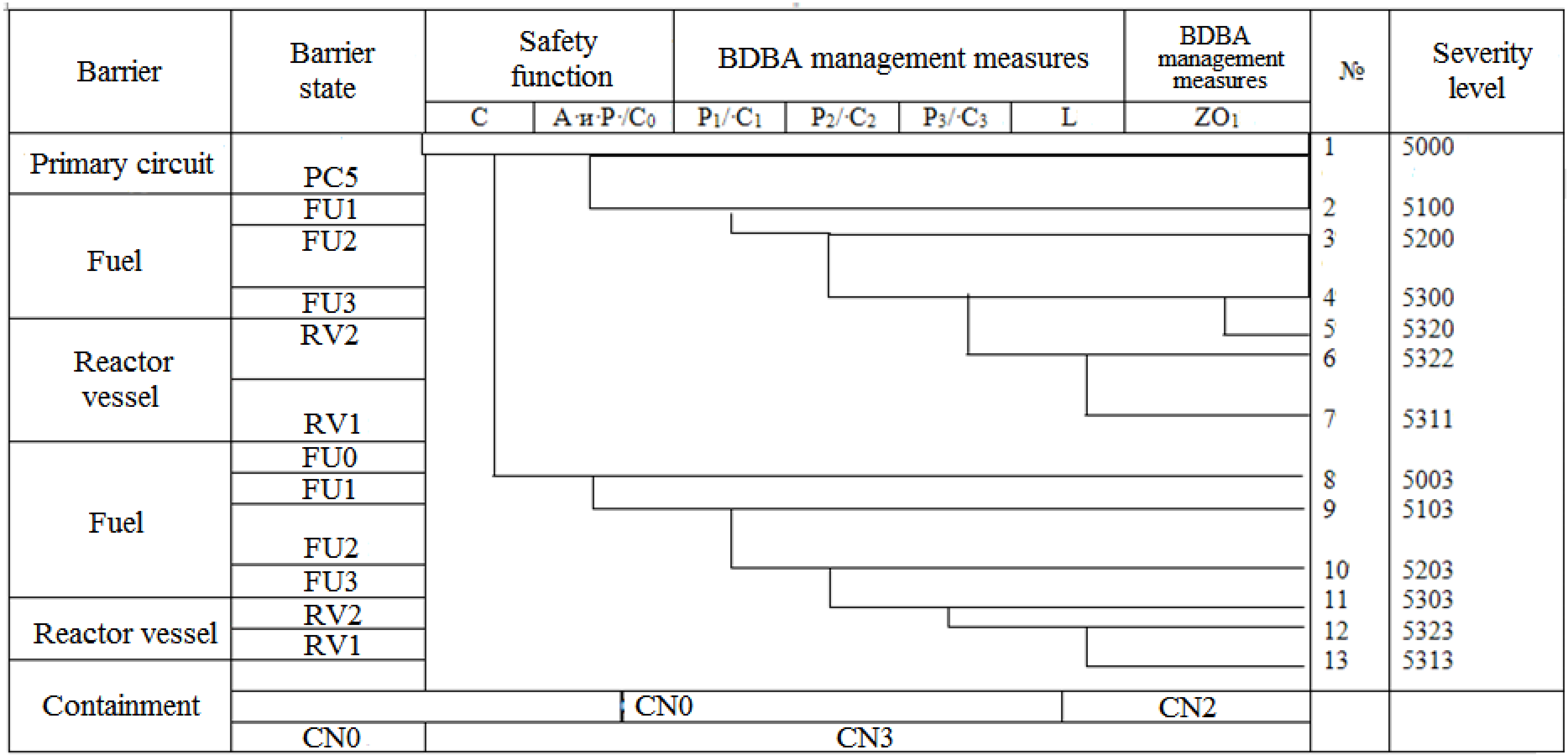


Plant Severity Level is the combination of specific states of physical barriers

Compatible barrier states				Number of severity levels	Severity levels codes
PC	FU	PV	CN		
0	1	0	0	1	0100
1	1 2	0	0 1	10	1100, 1101 1200, 1201
	3	0	0 1		1300, 1301,
		1	1		1311
		2	0 1 2		1320 1321 1322
2	1 2	0	0 1	9	2100, 2101 2200, 2201
	3	0	0 1		2300 2301
		2	0 1 2		2320 2321 2322
3	1 2	0	0 1	10	3100, 3101 3200, 3201
	3	0	0 1		3300, 3301
		1	1		3311
		2	0 1 2		3320 3321 3322
4	1 2	0	0 3	11	4100, 4103 4200, 4203
	3	0	0 3		4300 4303
		1	1 3		4311 4313
		2	0 2 3		4320 4322 4323
5	1 2	0	0 3	11	5100, 5103 5200, 5203
	3	0	0 3		5300 5303
		1	1 3		5311 5313
		2	0 2 3		5320 5322 5323

Example of Generalized Event Tree



Development of Severe Scenarios

Severity level 5000

Severity level 5000 + Failure of Accident management set A

Severity level 5000 + Failure of Accident management set B

Severity level 5100

Severity level 5100 + Failure of Accident management set K

Severity level 5100 + Failure of Accident management set L

Severity level 5200

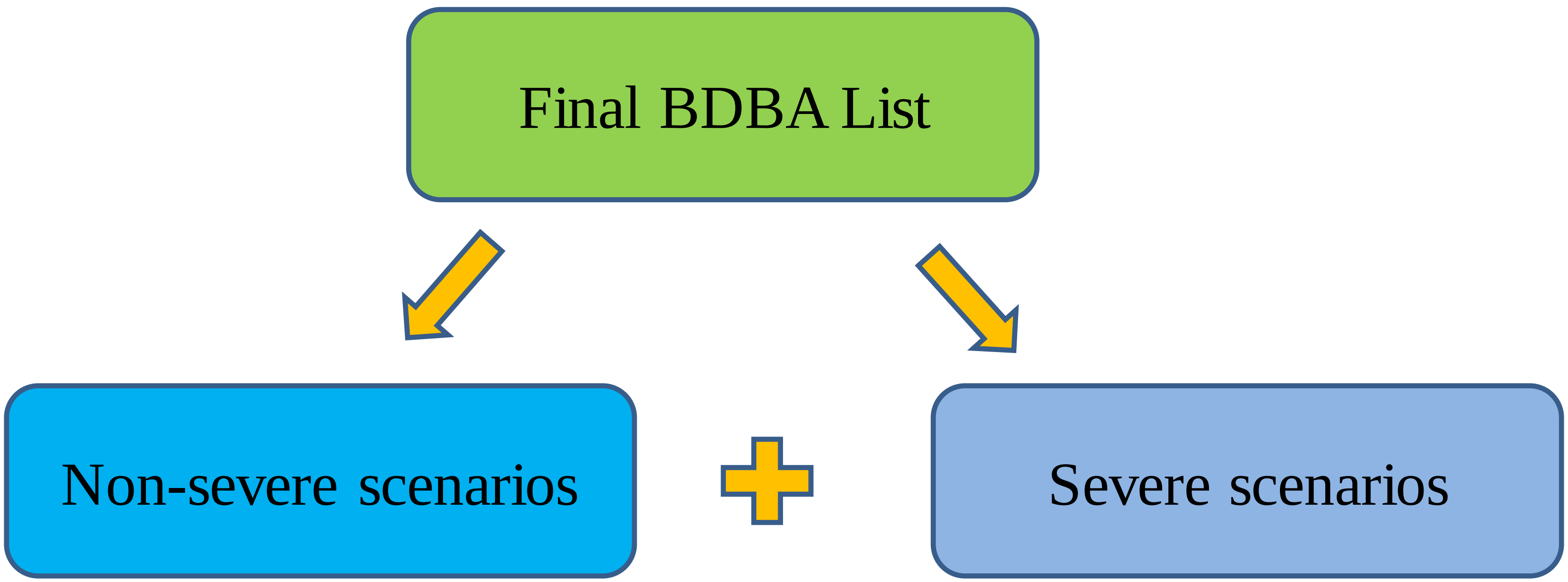
… …

Severity level 5300

Severity level 5320

… …

Final BDBA List



Conclusions

1. Proposed formal algorithm enables developing BDBA list which is representative from the point of view of accident management strategy
2. The BDBA list covers both severe and non-severe scenarios
3. It shall be verified further that BDBA management guideline covers all accident scenarios included into final BDBA list

Thank you for your attention!

Picture: SEC NRS Office in Moscow